EXPERIMENTS ON A CENTRIFUGAL FAN BLOWER

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Experiments on a Centrifugal Fan Blower.

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The following thesis is presented as exacted by the course in Mechanical Engineering, but before entering upon the subject matter it would be well to consider the circumstances and conditions of the general knowledge of the fan blower and the effecting of practical results, which in this case as in many others of an experimental character the application of theory to practice has been very difficult if, as in some particular instances, effected at all.

In the beginning, there is such a diversity of opinion as to the fundamental principles of the fan blower that it was determined to make the experiments independently.

That this difference is not due to want of experimental tests and data is apparent

upon glancing over any well known engineering index, but has been due mainly to two defects "what to observe, and how to observe it. Unless the fundamental principles of the action of the fan are kept constantly in mind, and all theories, calculations and observations based upon it, they possess but historic value, if that.

In experimenting with such a medium as air, its lightness, elasticity, and susceptibility to all changes of pressure, temperature humidity, small changes in one influences the others, all acting and reacting upon one another, thus making exact calculations for nearly every case necessary.

Considering the small quantities involved and their relations to one another the observations must be made with as small a limit of error as possible and this is considerably more difficult than

is at first imagined.

The fan used was a Sturtevant Monogram No. 4. The diameter of the wheel was 17 inches, width at periphery 4½ inches. There were 6 blades each 3⅞ inches long, having an area of 18 square inches, being of trapezoidal shape.

There were two inlets 10 inches in diameter, one on each side. One of these was partially obstructed by a pulley 6 inches in diameter while the other was obstructed, partially, by the shaft bearing 2 inches in diameter: Accounting for these obstructions the total inlet area was 66.270 square inches. The diameter of the shaft was 1¼ inches, the bearing 5 inches long at each end. The vertical diameter of the case through the centre of the shaft was 30" inches, the horizontal 27 inches, and the wheel was placed

3 inches eccentrically on the end. The outlet was 10½ inches, outside diameter, and over this a galvanized iron pipe 10½ inches, inside diameter was fitted. This pipe 5 feet long was provided with a taper, 11 inches long, of 3½ degrees making the diameter 9¼ inches.

There were six tapers used to vary the area of discharge, made of the same material and angle of 3½ degrees and made to slide over the taper on the large pipe. They were the following

Number 1	3.915" diam.	12.037 sq. in. = 0.0836 sq. ft.	
2	5.455" "	23.655 " " = 0.1643 " "	
3	6.724" "	35.510 " " = 0.2466 " "	
4	7.875" "	48.706 " " = 0.3385 " "	
5	8.78" "	61.945 " " = 0.4303 " "	
Full	9.25" "	65.4048 " " = 0.4667 " "	

The power was furnished by a 5 kilowatt Vallet motor to which the blower was belted.

directly. This motor was of the horse shoe type, shunt winding 99.52 ohms resistance. The armature had series coils of which there were six, had a resistance of .188 ohms. This brushes were of carbon, there being two placed side by side for each terminal.

The belt was 4" wide, 32 feet in length, was stretched to tension by position, and of single thickness.

The power was measured by means of Weston instruments, voltmeter No. 93 and ammeters Nos. 94 and 97, which were connected in parallel. This was corrected for the efficiency of the motor, by the stray power method, and for the belt slip by noting the number of the revolutions of the belt, which was done at the same time as the speed of the brake was ascertained.

The speed of the brake was obtained by means of a speed recorder reading from

revolutions, being connected to the blower by a soft rubber tube. The spindle of the speed counter passes through the thrust plug of the blower. The time was noted on a stop watch of a convenient number of revolutions, usually 200 thus determining the number of revolutions within .1%

The pressure was measured by means of the usual U tube water manometer, in connection the 10 inch pipe. The height of the column was measured by means of a scale, graduated into inches and tenths, in black and ounces and to the corresponding to the temperature of 20° F. This scale was made to slide within the legs of the U tube, A telescope provided with a horizontal cross wire was used to measure the height and read the scale. By these means the reading could be made within $\frac{1}{10}$ of $\frac{1}{16}$ inch = .00625 inch.

In the attempt to measure the quantity

of air entering the inlet box, 24" x 24" was built of flowed & grooved boards and fitted surrounding the blower, and in the top of this was an opening of 24 inches diameter or 3.006 square feet in area. In the side of the box holes were made for the belt, and after the belt had been running some time and drawn tight by the adjustable screw on the motor, pieces of baste board were fastened upon the side of the box so as to just clear the belt; in this way the air due to the opening, disregarding the fact that the belt travels in opposite directions in passing through the two holes, would be but 1/50 which, considered with the error due to the inaccuracy of the anemometer, see paper by Mr Regan London Institution of Civil Engineers (London) pg 345 vol CXI. in which he explains, shows the anemometer to be reliable within only 5%)

It might be stated here that nothing was taken for granted, but the question being fully

investigated (as far as was possible) as it was met, before being disposed of, and having no theory to prove, and everything to ascertain this could be done discriminately.

The thesis can be divided into four parts.

First — A means for measuring the quantity of air under pressure flowing through a pipe of known area.

Second — The variation of pressure and volume of air discharged with different sized openings at constant speed of the blower.

Third — The variation of pressure and volume of air discharged at different speeds of the blower.

Fourth — The analysis of the forces acting in the blower and the accounting for them if possible.

In that each of these parts depends upon that preceding, it needs no special reason for beginning experiments with a view of solution of the first part.

The first part may be divided into two parts,

(a) the measurement of pressure in a tube through which air is flowing.

(b) the measurement of the velocity, and also the pressure producing the velocity, of the air in a tube.

In the measurement of pressure in a tube through which air is flowing, it is assumed, that the air is perfectly elastic the pressure in all parts of the tube is the same and it is evident that this pressure should suffer no variation whether the air is or is not flowing through the tube.

When the experiment of placing a tube, with the plane of its end and orifice perpendicular to the horizontal diameter of the pipe, different distances in the pipe, along a vertical diameter, was tried it was found that the pressure gradually diminished from the top of the pipe to the bottom, at which point a vacuum was attained.

Experiments were at once begun to determine the cause of this variation of pressure and knowing the cause of the evil effect a cure.

Accordingly a number of tubes were prepared having different sized openings in them, the plane of the orifice and end of tube coinciding, and were placed so that this plane was parallel to the horizontal diameter of the pipe.

Most of the tubes were cylindrical but some were made flattened out at the end, thus giving and orifice of but .005 square inches in area.

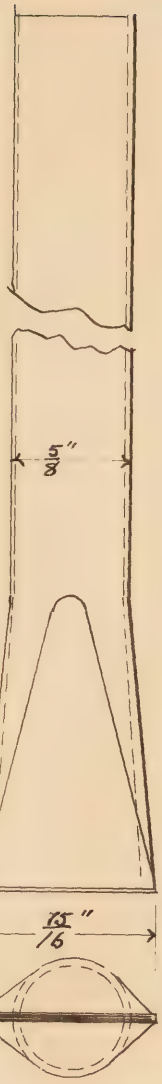
Some cylindrical tubes were also prepared having their orifices in the side of the tube, the ends being closed. These tubes were placed in the same position as the others.

The following experiments were made with a constant speed of 1818 revolutions per minute of the blower. The pressures noted are in $\frac{1}{16}$ inch of the water column. The columns otherwise explain themselves.

Scale - 1" = 2"

No.1

No.5



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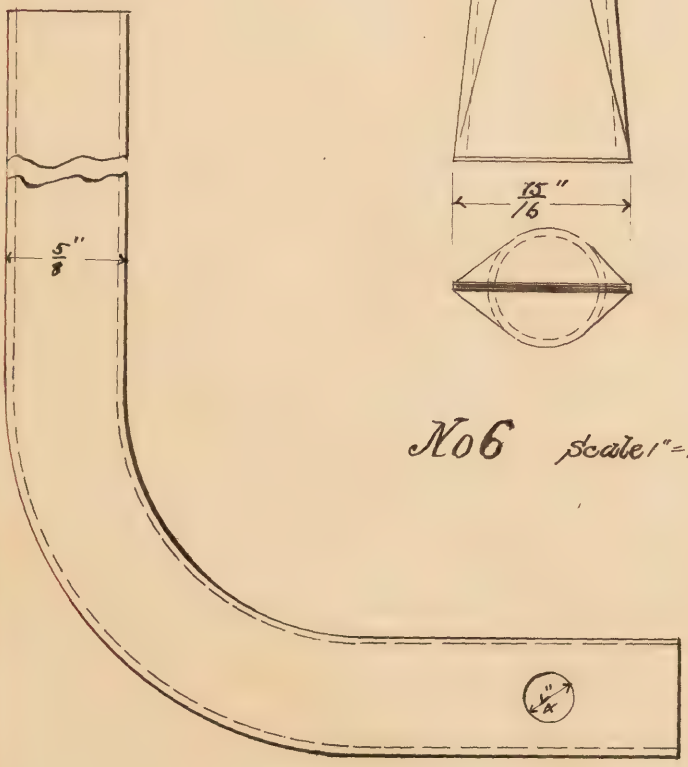

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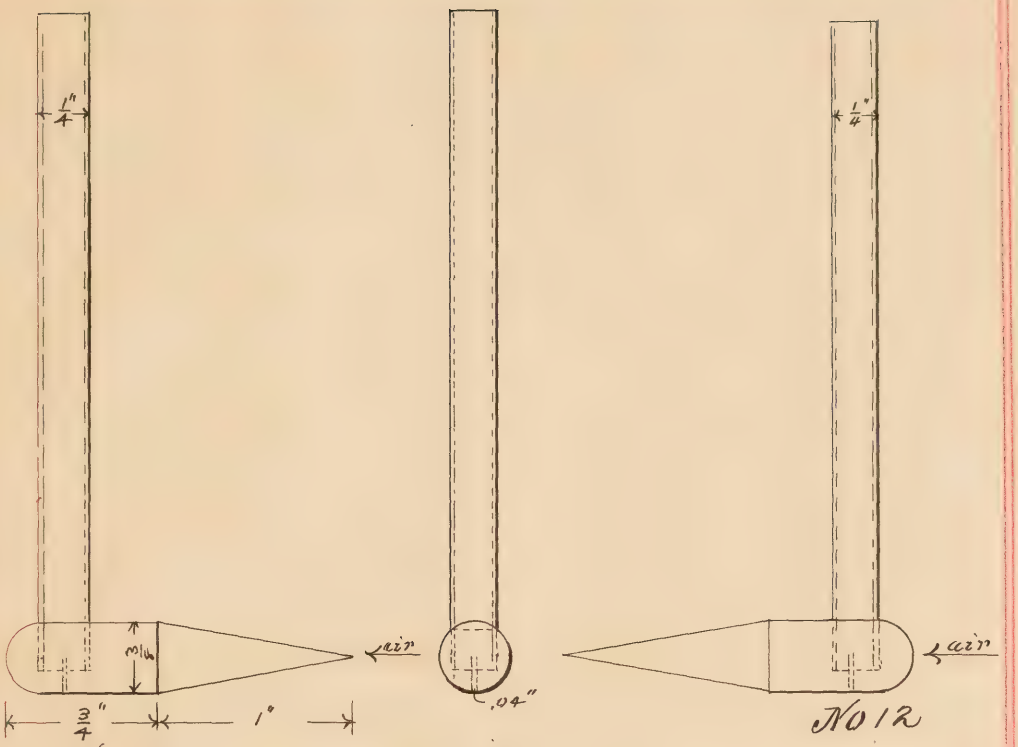

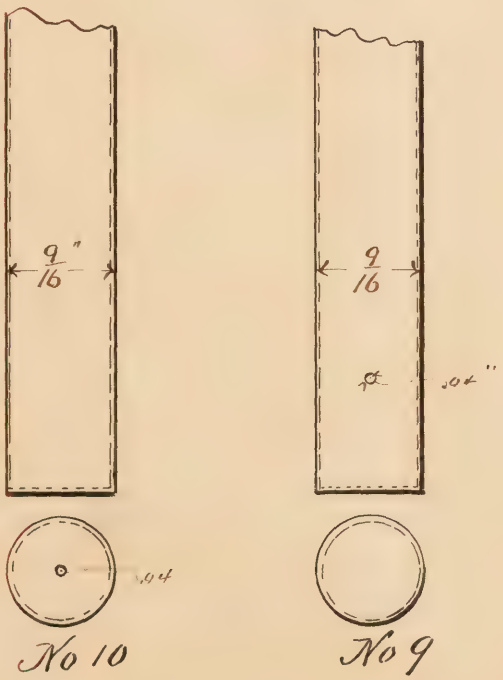

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— Table No. 1. —

Number of Experiment	Distance in Pipe inches	Number of Tube 9	7	6	1	8
A 2626	1	17.0	8.7	12.2	7.0	16.8
A 2627	3	17.0	7.0	11.0	1.1	16.8
A 2628	5	16.8	-5.6	10.0	-2.9	16.8
A 2629	7	16.8	2.3	10.0	-5.5	16.8
A 2630	9	16.8	1.1	11.0	-10.0	16.8

— Table No. 2. —

Number of Experiment	Distance in Pipe inches	Number of Tube. 11	8	1	5	6	7	12
A 2111	1	12.5	17.8	7.5	6.0	11.9	11.1	13.0
A 2112	3	12.8	17.8	0.8	-3.2	12.0	7.9	13.2
A 2113	5	12.6	17.8	-2.0	-6.0	12.8	6.4	12.5
A 2114	7	12.3	17.8	-5.1	-8.9	12.7	4.8	12.3
A 2115	9	12.3	17.8	9.7	-18.8	12.7	2.2	12.3

Table No. 3

Number of Experiment	Distance in Pipe diameters from side of Pipe	Pressure in Inches of Water. Number of Test. 10	10	8a
A261	1/4	11.2	9.9	15.2
A262	1/2	6.3	7.0	15.2
A263	1	4.5	3.1	15.2
A264	2	2.0	3.0	15.2
A265	3	3.0	2.0	15.2
A266	4	4.3	2.3	15.2
A267	5	5.1	4.6	15.2
A268	6	5.9	5.5	15.2
A269	7	6.9	5.5	15.2
A2610	8	7.0	3.7	15.2
A2611	9	7.9	4.4	15.2
A2612	10	6.2	5.7	15.2

Table No 4

Number of Experiment	Distance from top of Pipe	Pressure in Inches of Water. Number of Test. 10	8a
A2613	1/2	11.4	15.2
A2614	1	9.8	15.2
A2615	2	8.4	15.2
A2616	3	7.3	15.2
A2617	4	4.3	15.2
A2618	5	3.0	15.2
A2619	6	-1.0	15.2
A2620	7	-3.6	15.2
A2621	8	-3.3	15.2
A2622	9	-3.5	15.2
A2623	10	-6.0	15.2

An examination of the tables will show two facts, first, that the greater the velocity through the pipe the greater is the decrease in pressure as the tube is advanced into the pipe, and that at least distance in the readings more nearly coincide. The experiment was at once made of placing the orifices in the plane of the top of the pipe or zero inches within the pipe. The result of this was that all of the tubes indicated the same pressure.

There was but one conclusion to be drawn from this and that was; that the decrease of pressure across the pipe was due to what might be called an induced effect. This would be caused by the air impinging on the tube and the flowing off at an angle and also scooping the air out of the orifice due partly to two causes, the tipping of the tube slightly due to the pressure on it and the

fact that the tubes might not have the ground at exactly right angles to its length.

- The effects of the slightest tipping of the tube may be shown by the sketch, in which the tube is in an exaggerated position.

Knowing then the cause of the inductive action a brass tube was fitted with a steel plate $2\frac{7}{8}$ inches in diameter, its edge turned to a sharp line, and when this tube was placed so that the plane of the plate was in the plane of any diameter of the pipe or parallel to the direction of the air current the pressure measured was identical at all points in the pipe.

- The experiments showed that the use of

the orifice made but little difference, though the water column was somewhat more steady.

A hydraulic engineer M. Le Roy made a form of tube similiar to 8, number 8a, to measure the static, in contrast with dynamic) pressure of water flowing through a pipe, for the experiments it is believed best, however, to use a tube equipped with a plate, as the larger (the larger) the plate the more uniform will be the flow thereon, and the tube 8 and 8a may be considered as provided with a long but very narrow plate.

(b). The measurement of the velocity, and the pressure producing the velocity of the air in a pipe.

That the velocity of flow and the pressure producing it are connected by some formula needs not to be demonstrated.

The law of flow of fluids under pressure was discovered by Torricelli and published in his

"Del moto dei gravi" in the year 1600 to be

$$v^2 = 2gh.$$

This was verified experimentally by Hutson, Engineering, Volume XII pg. 1—, after a most complete and exhaustive set of experiments.

It may be proved from the laws of kinematics

$$s = at \quad \text{and}$$

$$h = \tfrac{1}{2} st$$

$$\therefore h = \frac{at^2}{2}$$

$$\therefore s^2 = 2ah = v^2 = 2gh.$$

Knowing the law, it but remains to measure the height h. Pitot proposed to measure this by means of the tube which bears his name; consisting of one tube, with the plane of the orifice directed to receive the impact due to the reduction of velocity, the other to measure the pressure simple, as in case (a). It was not the success that was at first imagined and it remained for the engineer M. D'Arcy to complete it. He tapered the tube to receive

the dynamic pressure or that due to the impact of the flowing air, and to make a tube exactly alike it, with a hole at the side, the end being closed, and placing these two tubes side by side. The openings were made very small. With a tube very much like this Professor S. H. Peterson made some experiments with natural gas and found that the results the best of any known method. A very complete set of experiments were made by some German engineers and published in the Anlagen zum Haupt Berichte der Preuss. Schlagwetter Commission.

With the idea to see what difference the size of opening made in the velocity tube, in order that the proper one be chosen the following experiments were made.

A number of hard glass tubes $\frac{3}{8}$ inch internal and $\frac{1}{2}$ inch external diameter were bent and tapered so that the orifice was $\frac{3}{8}$" $\frac{1}{4}$", $\frac{3}{16}$", $\frac{1}{8}$" $\frac{1}{16}$" and $\frac{1}{16}$", the orifices having been

ground on an every wind so that their plane would be at right angles to the direction of flow.

The readings of the pressures were made with the speed of the blower constant, and as all the other conditions were the same the velocity must have been the same in the pipe.

With this condition of things there was no difference in the pressure indicated by the velocity tubes no matter what their age of efficiency."

That this should be so appears not only right but inevitable as the air in the tube is compressed due to the impact of the air moving in the pipe, and that whatever pressure produces the velocity that will be produced by the velocity, now being lost. If the air in the tube and upper part of the one leg of the water column were compressed more than that due to the impact

of the moving air it would be speedily reduced and "vice versa" Again we can consider that the air in flowing through the pipe is composed of a number of small cylinders of air and that one of these is used for the measurement of the head producing the velocity of flow.

As this pressure includes the static pressure in the pipe, in order to find the head producing velocity alone, the static pressure must be subtracted from the total pressure read, and this can be done very simply by connecting the tube having the combined pressures to one leg of the U tube and that having the static pressure to the other the difference in height being the height to be substituted in the formula

$$v^2 = 2gh.$$

$$\text{or } v = \sqrt{2gh} = 8.02\sqrt{h}$$

or if h be in feet of water $v = 8.02\sqrt{801.2h}$

$$v = \text{feet per second} = 227.\sqrt{w}$$

Following out the plan laid down above one test at each of zero and .16 square feet opening have been made, but it is thought best to wait until the others have been made as no comparisons nor any law of action could be deduced and they will therefore appear in their proper place among the tests of the entire number of different sized openings in a supplementary paper.

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